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Title : Current-Fed Switched Inverter and Its Derivatives
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Abstract

Renewable energy systems have gained much popularity due to their non-emissive nature and abundance. Due to the rapid contraction of the fossil fuel reserve and its detrimental effect on the environment, there is a growing trend towards exploring different renewable energy sources and maximizing energy harvest from them. These comprise of solar photovoltaics (PV) system, wind turbine system, hydel power system, geothermal energy system, wave and tidal energy system, etc. Solar PV systems have become more popular and reliable renewable energy source as the solar irradiation on the earth surface has a definite pattern and its availability is predictable. The solar PV module has a characteristic of delivering maximum power at a particular PV module terminal voltage. Thus, it requires for power conditioning circuit to extract the maximum power. The output of the power conditioning circuit also needs to feed the extracted power to the load. As loads are connected to a particular DC or AC voltages (termed as grid voltage), the power conditioning circuit (also called power electronic interface) needs to produce the particular voltage level at its output. Typically, a PV module has a low output voltage (12 V – 48 V for 40 W – 400 W PV module) and the grid has higher AC voltage (110 V or 220 V rms). Thus, the power electronic interface needs to provide a high voltage boost. Voltage source inverter (VSI) based topologies are used as power electronic interface but they suffer from some major drawbacks like: a) VSI cannot provide any boost at its output, b) the upper and lower switches of any leg of a VSI cannot be gated simultaneously, c) dead-time between switching signals of upper and lower switches need to be provided which causes output voltage distortion. Usually boost type DC-DC converters are cascaded with VSI to provide boost feature but the other drawbacks could not be eliminated. Impedance source inverters are proposed in order to eliminate these drawbacks by providing high boost inversion in a single-stage power conversion with shoot-though operation which enhanced system reliability. The major drawbacks of the first developed impedance source inverter, Z-source inverter, are: a) it uses high number of passive components with high consistency, b) it draws discontinuous input current for the DC source, and c) the modulation index of the inverter bridge is limited by the shoot-through duty ratio which leads to poor utilization of the DC-link voltage and higher voltage stress on the inverter switches. Quasi-Z-source inverter provided continuous input current property but the other drawbacks remained. Many other ZSI based inverter topologies are proposed in the literature which raises the inverter gain using switched inductor/switched capacitor/coupled inductor based networks but addressing all the three drawbacks of ZSI remained a challenge. In this thesis, a high boost inverter named Current-Fed Switched Inverter (CFSI) is proposed which provides similar boost compared to ZSI using half of its passive components and draws continuous input current from the DC source. To enhance the boost capability of CFSI, a coupled inductor based CFSI topology named Trans-CFSI is proposed which achieves very high boost at lower shoot-through duty ratio by increasing the coupled inductor turns-ratio beyond zero. This enables Trans-CFSI to extend the modulation index which in turns results in better DC-link voltage utilization and lower voltage stress on the inverter switches. Another coupled inductor based high boost inverter is proposed in this thesis which is named as Improved Trans-CFSI. Improved Trans-CFSI provides high gain at lower shoot-through duty ratios by increasing the coupled inductor turns-ratio in a very narrow range of zero to unity. Improved Trans-CFSI provided higher gain with lower total inductor turns than the inverters in its class. In order to preserve the lifespan of renewable sources and storage elements, a current ripple cancellation technique is developed which can minimize input or output current ripple in a power converter. The ripple cancellation technique is based on inductance matching in a coupled inductor based LL-LC filter network. The current ripple cancellation technique is applied to CFSI and boost converter for input current ripple cancellation and to buck converter for output current ripple cancellation. A hybrid

converter structure of CFSI is proposed for DC Nanogrid to cater both AC and DC loads simultaneously while fed from a single DC source. The hybrid CFSI structure reduced power conversion stages from multi-stage power conversion (using traditional boost converter and VSI based Nanogrid) to a single-stage power conversion. The thesis has been organized into eight chapters. In Chapter 1, a brief introduction of traditional solar inverter systems has been given. The need of high boost inversion and drawbacks of traditional boost converter cascaded VSI topology is discussed. The major contributions of the thesis and the organization of the thesis are also detailed. Chapter 2 provides an overview of the high gain impedance source inverter topologies. The boost factor of the inverters is provided for gain comparison. The advantages and shortcomings of the impedance source inverters are also discussed. The characteristics of an ideal high gain impedance source inverter are listed. In Chapter 3, the circuit development of the Current-Fed Switched Inverter (CFSI) is discussed in detail. The steady-state operation of CFSI is explained and the mathematical relation between its input and output parameters is established. A constant boost control method of pulse width modulation (PWM) is also described. The performance of CFSI is compared with the state-of-the-art inverters unveiling its advantages and disadvantages. The steady-state operation of CFSI is also validated in experiments. In Chapter 4, a coupled inductor derived high boost inverter of CFSI, named Trans-CFSI, is proposed. The transformer action of the coupled inductor is described in detail which enables Trans-CFSI to achieve higher gain than CFSI, ZSI, and q-ZSI. The steady-state analysis of Trans-ZSI is provided and relation between its input-output parameters is established. The dependence of the inverter gain and switch voltage stress on the coupled inductor turns-ratio is studied. The detailed performance comparison between various coupled inductor based high gain inverter and Trans-CFSI is done. Simulations and experiments on laboratory prototype are done to verify the steady-state of operation of Trans-CFSI for various load conditions. In Chapter 5, another coupled inductor based high gain, CFSI derived inverter, named Improved Trans-CFSI, is proposed. The operating characteristic of the inverter is described along with its input-output relations. The performance of the Improved Trans-CFSI is compared with other coupled inductor based high gain impedance source inverters to uncover its operational advantages. The operation of the Improved Trans-CFSI is validated in simulations and experiments for various load conditions. In Chapter 6, a coupled inductor based LL-LC filter network is proposed for input or output current ripple cancellation in a power converter. The filter network is applied to CFSI, boost converter to minimize the input current ripple and buck converter to minimize output current ripple. The effect of parameter sensitivity on the performance of the ripple cancellation network is discussed. The operation of the LL-LC filter network is validated in experiments. In Chapter 7, application of CFSI in a DC Nanogrid is presented in detail. A hybrid converter structure is formed using CFSI feeding both AC and DC loads simultaneously with improved cross-regulation. The operation of the hybrid CFSI based DC Nanogrid is validated in experiments in dynamically varying AC and DC load conditions. Chapter 8 provides concluding remarks along with the future scope of research related to this thesis.

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Title : *Development of distributed control schemes for energy storage systems using distribution load patterns*

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Abstract

In distribution system, peak load demand growth of customers is more than the average demand growth and such peak demand may occur for a few hours on a few days in a year. So, the distribution system equipment such as transformers may get more stressed due to overloading and also these will be aged more rapidly. To cater the enhanced load requirement, there would be a need to upgrade the existing distribution system by replacing aged and over stressed transformers and/or re-conductoring distribution lines with heavy wires. In replacement, the equipments are sized to meet the load growth for next 15-20 years and hence, a huge investment is required for such new equipments life. Energy storage can be used to defer or avoid the equipment upgrade and life extension. Electrical energy storage is identi ed as a potentially multi-faceted technology for application in the future electrical power systems. This technology can enhance grid performance by balancing generation and demand, reducing variability of renewable gen- eration, utilizing renewable generation peaks, managing peak demand, support to electric vehicles (EVs) etc. Energy storage, which is entirely resource neutral, facilitates to inte- grate electricity from any source into a more resilient and reliable grid. Energy storage can provide reserve and exibility for power system operation with and without high penetration of intermittent renewable generations. For an extension of the life of aging equipments, a small amount of storage can su ce to reduce the peak demand served by the equipments. A methodology is to be developed for evaluating the amount of energy stor- 1 age needed to defer transmission and/or distribution (T&D) capacity upgrades. The key elements needed to demonstrate the viability for deferral or life extension are high T&D cost, high peak-to-average demand ratio, modest projected overload, slow peak demand growth (rate), uncertainty about the timing and/or likelihood of block load additions, T&D construction delays or construction resource constraints, etc. Aforementioned key elements can be assessed with past information of electrical de- mand in the distribution system. Thus, the historical information of loadings on substa- tion helps in evaluation of size of renewable sources and energy storages for peak shaving and distribution system upgrade deferral. Extracting valuable information from a large volume of load data are the tedious task. Regular and irregular consumptions detections help utilities in planning and making strategies in providing reliable and e cient electricity transfer from generation to end users. Peak load demand can be assumed an aberration in end use consumption of electricity, and its assessment and curtailment is a complex prob- lem which requires considerable attention within smart grid initiatives. Aforementioned problems are related to the electrical load patterns in di erent regions. Data mining, computation process for discovering patterns in large data set, involves machine learning, arti cial intelligence, statistical analysis, etc. Clustering methods, which are unsupervised approach and part of data mining, classify the data set into groups with the similarity features. Most of the literatures, pertaining to load data classi cation, focussed in identi- cation of regular consumptions. In identi cation of irregular consumptions, in a very few literatures, supervised approach and statistical methods are applied on whole data set. In the literatures, the works lack for sizing renewable sources and energy storage, based on historical loadings on substations, for T&D upgrade deferrals and peak shaving operation in distribution systems. The future power system, which is going to be highly interconnected with multiple entities, will require precise regulation at di erent operating conditions and a very little tolerance for unmatched consumption and supply. Any latency in the system and errors in the information used for decision makings may disturb the proper functioning of the system and the system will be vulnerable to cyber-attack. A multi-agent system (MAS) is gaining attention in design of di erent control schemes in networked systems. MAS can provide

many layers of control and optimization algorithms for future grid which is to be resilient in its operation. Agents, with interaction in group, can cooperate or compete to achieve a global objective. The agent behaviour depends on the information of the group possesses and the interactions to be done with other agents of the group. As the behaviour 2 of the agents is prone to be cyber-attacked so a mechanism is to be devised for mitigating such attacks on MAS used for distributed control scheme. The optimal control scheme, one of the classical control approach, used to optimise the performance of the dynamics of the system over time. In distributed optimal control scheme, performance index is targeted to achieve while optimizing the dynamics of all the components of the distributed control system. In MAS, with the implementation of distributed optimal control, the performance of each agent's dynamics can be improved. Cyber-physical system (CPS) of smart grid is basically amalgamation of computa- tional and physical properties found extensively in multiple domains of electricity grid. For networked monitoring and controlling purposes, embedded wireless sensor-actuator- controller is the backbone of CPS. The basic idea behind integrating physical and virtual world is that there is seamless collection of useful information of the physical world and apply this information in various functions of the system. Cyber-physical system creates new theory to build dynamic control based on information. So, di erent control designs are based on information generated at numerous scattered nodes in the power systems. The major challenge in networked-CPS is to guarantee stability in the open/closed loop system while utilizing smart grid infrastructure. The major endeavors are needed in design of distributed control scheme in controlling the various distributed energy storages which are connected in network. The agents possess intrinsic capability to take autonomous decisions at local level, thus, MAS can provide solutions to the challenges of the future grid as CPS. There is a need to develop a distributed optimal control scheme for MAS in the presence of cyber-attack on some of the agents such that performance of the system at both microscopic and macroscopic levels can be improved while mitigating the e ects of cyber-attacks. In view of the above, the main objectives behind the research work carried out in this thesis are as following. To develop clustering technique which can identify regular and irregular consump- tions, simultaneously, with less computational burden. To size, based on historical load data, the substation scale battery energy storage for peak shaving in the power distribution system and develop its real time control scheme. To develop agent based distributed control scheme, with suitable communication protocol strategy among the agents, for power mismatch in the distribution system 3 with equal participation of distributed energy storage systems (DESSs). To develop agent based distributed control scheme for distributed energy storages , based on agents' behaviour, in the presence of cyber-attack on some of the agents and ensure convergence in the scheme. To develop agent based secure distributed optimal control scheme for distributed energy storages to improve the overall performance as a cost function of the system under cyber-attack scenarios.

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Title : Development of Vision Based Automatic Facial Expression Recognition Systems Using Machine Learning Algorithms

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Abstract

This thesis work is concerned with the development of an Automatic Facial Expressions Recognition System (AFERS) which can infer different emotions or intensities of emotion using facial expressions. Initial attention goes to recognition of six fundamental expressions such as happiness, sadness, disgust, anger, surprise and fear. The well established databases: MMI and extended Cohn-Kanade are used for experimental purposes. This thesis work also addresses the recognition of higher level emotions such as shoulder pain intensity, using the UNBC-McMaster shoulder pain expression archive database. The database has spontaneous, un-posed and unscripted, behavioral observations in individuals that have clinically relevant pain which make recognition task even more challenging, mainly due to lack of enough training and testing data. The major contributions of this thesis are as follows: 1. Emotion Recognition using Extended Self Organizing Map (ERESOM): An automatic facial expressions recognition system is proposed to recognize six fundamental emotions. ERESOM has two aspects: automatic facial features extraction and development of a multi-class classifier using extended self-organizing map (SOM). ERSOM uses 26 dimensional geometric facial features extracted from regions such as eye-brows, left and right eyes, nose and lips. A novel multi-class classification methodology is ntroduced using SOM. The learning approach takes advantage of both supervised and unsupervised techniques. The experimental results of ERESOM classifier using the geometric features proves its efficiency in recognizing six fundamental emotions while ensuring significant increase in average classification accuracy over RBFN, MLP and SVM. 2. A Emotion Recognition using Deep Network (ERDeN): The fusion of 26 geometric features and 236 LBP features (appearance features) using autoencoders is the hallmark of this approach - a novel idea to achieve a better representation of the facial attributes. An improved SOM based classifier is also introduced that further enhances classification accuracy. The fusion and classifier has been achieved in a deep network configuration consisting of autoencoders and extended SOM network. 3. Handling Multi-class Imbalanced Data (HaMID): A multi-class imbalanced data handling technique is proposed that includes sparse information extraction using directional sample space search and class prioritized synthetic data generation avoiding border violations. The technique is applied on Shoulder pain archive database to recognize 15 levels of shoulder pain intensity using facial expressions. An undersampling technique is proposed that operates on the majority classes to make them more compact by efficiently removing redundant from the class. The methodology also maintains the diversity of the data samples of the original class. It is achieved using the angular information among data samples, which is a novel contribution. An oversampling technique is proposed to generate synthetic data in the minority classes. The algorithm checks for the boundaries of other classes in the neighborhood of a data sample and generates desired number of samples in a minority class. A regression model is created using mixture of Gaussians to recognize 15 different intensity levels in the final balanced dataset. Performance measures are analyzed for the proposed algorithms and compared with two existing techniques: SMOTE, ADASYN and random sampling.

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Title : TransceiverDesignsforRelayaidedMIMO Interference Systems
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Abstract

Cooperative relaying is a promising technique for mitigating the fundamental limitations of fading and interference in a multi-user wireless network. In this thesis, we address the problem of linear transceiver design for relay aided MIMO interference systems, where a finite number of amplify and forward (AF) relays assist multiple transmitter nodes to communicate with their respective receiver nodes. We start by assuming perfect channel state information (CSI) of all the links. Sum-rate maximization and sum mean squared error (MSE) minimization based transceiver designs have been proposed in the existing literature. Although these designs are useful from the perspective of system design, none of them will guarantee fairness among different links. So we address two transceiver design problems aiming to achieve fairness among all the users' data streams: one is minimizing the maximum per-stream MSE and the other is maximizing the minimum per-stream signal to interference plus noise ratio (SINR) of the received signals among all the receiver nodes, both of which are subject to individual transmit power constraints at the transmitter and relay nodes. Since the resultant optimization problems are non-convex with matrix variables, a globally optimal solution can not be guaranteed. Therefore, we present sub-optimal algorithmic solutions in which the beamforming matrices at all the transmitter, receiver and relay nodes are jointly computed in an iterative manner. In particular, each iteration of the proposed algorithms consist of solving three sub-problems for updating the transmitter, receiver and relay matrices respectively in a cyclic order. We show that in the case of MSE optimization problem, the transmitter and relay matrices design sub-problems can be formulated as convex conic optimization problems, which can be efficiently solved by using interior point methods. Whereas in the SINR optimization problem, the transmitter and relay matrices design sub-problems can be formulated as quasi-convex optimization problems, which can be exactly solved using the classical bisection method and convex feasibility checking. However in this case, each iteration would require solving a sequence of convex feasibility problems each for the transmitter and relay matrices, which is computationally expensive. Therefore, we also propose a method for inexactly solving the transmitter and relay matrices design sub-problems by solving their inverse problems. Simulation results show that the SINR based design outperforms the MSE based design in terms of minimum user rate and BER performance. The assumption of having perfect knowledge of channel is however often unrealistic in practice. Due to channel estimation errors, limited quantized feedback and outdated channel estimates, there is always a mismatch between actual and estimated channel. Generally, there are two different ways to model CSI errors: the stochastic model and the deterministic model. First we consider the stochastic model for CSI uncertainty such that the imperfect CSI consists of the first and second order statistics of the true channel. The channel of each link is modeled in the form of a Gaussian random matrix with estimated channel matrix as the mean value and its estimation error covariance as the covariance matrix. We adopt a statistically robust transceiver design approach which guarantees a certain system performance averaged over all the channel realizations. We consider a robust transceiver design problem to minimize the sum of averaged MSEs of all the receiver nodes subject to a transmit power constraint at each transmitter and relay node. We first derive an expression for the averaged MSE. Using that expression we present two iterative algorithms for obtaining sub-optimal beamforming matrices at the transmitter, relay and receiver nodes. Lastly, we consider the deterministic model for CSI uncertainty such that CSI error lies in a norm bounded region. The channel of each link is located within the bounded region around the estimated channel. We adopt a worst-case robust transceiver design approach, which guarantees a certain system performance for any channel realization in the uncertainty region. We present iterative algorithms for MSE based transceiver designs including sum-MSE minimization, minimizing the maximum MSE among all users and minimizing the total transmit power subject to MSE constraints at each receiver. For these problems, we use s-lemma (s-procedure) to convert semi-infinite conic optimization problems to convex semi-definite optimization problems (SDP). However the SDP based approaches are generally computationally expensive. So we present a cutting set based approach which uses an alternate sequence of optimization and worst-case analysis steps. This approach achieves similar performance with a reduced computational complexity as compared to the SDP-based approach.

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Title : Creation of Electric Double Layer in Thin Film Transistors with Charge Carriers to Achieve Low Voltage Operation

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Abstract

Thin film transistors (TFTs) are being developed for a wide range of innovative applications including active matrix LCD and OLED displays, RFIDs, sensor arrays due to the potential advantages of low cost fabrication using roll-to-roll printing techniques on flexible substrate. Among important characteristics of TFT, a sufficiently large channel current at low operating voltage is required to address many of the applications. As a result of low field effect mobility in amorphous semiconductors compounded with thick dielectric layers with low dielectric constant, a large operating voltage is normally needed to obtain adequate channel current. As a solution to this problem, in the present work, a new transistor design is proposed in which channel is created through formation of an Electric Double Layer (EDL) induced by electrons and holes. It is shown that when insulator is replaced by a semi-conducting layer of appropriate characteristics, large channel charge can be obtained at low operating voltage. Due to close proximity of mobile carriers, there is recombination and gate current which also determines the magnitude of channel charge. As a result, the proposed device is called a 'Current Induced Channel Transistor' (CICT) to contrast it with devices where channel is created through the field effect principle. The operation and limitations of the proposed transistor and performance of basic circuit blocks including display pixel circuits are illustrated through device-circuit mixed mode simulations. The thesis also presents an alternative realization of EDL based TFT structure in which high effective gate capacitance and associated large drain current at low operating voltage is achieved through creation of a trap assisted electric double layer at the interface. The use of dopants acting as traps ensures low recombination and high channel charge density. Simulation results are presented that validate the proposed mechanism and indicate that current enhancement by a factor of almost an order can be achieved with a trap density of 1019cm-3 at 0.3eV above HOMO placed 5nm away from the semiconductor/dielectric interface. Experimental evidence for the proposed concept was observed in amorphous-IGZO TFT with e-beam evaporated SiO2 which exhibited an order of magnitude higher drain current than expected from typical values of mobility. Although the drain current enhancement was observed due to naturally present traps within an un-optimized dielectric, the results point to the feasibility of obtaining high output current through deliberate incorporation of traps in the dielectric leading to formation of a trap-assisted electric double layer.

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Title **:** ***OnCooperation, Energy Harvesting, and Security in Cognitive Radio Networks***

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Supervisor **:** ***Banerjee Adrish***

Abstract

Due to the limited availability and rigid allocation of the spectrum, it has become difficult to accommodate the emerging wireless applications. This thesis explores one of the key enablers of the next-generation wireless networks leveraging the dynamic spectrum sharing, namely cognitive radio. To show the effectiveness of cognitive radio and the challenges associated with it, this thesis forays into three aspects of cognitive radio: 1) Cooperation; 2) energy harvesting; 3) security. Based on spectrum sharing modes in cognitive radio, we organize this thesis in three parts. The first part of the thesis focuses on the overlay mode, where an energy harvesting secondary network helps the primary network relay the information and in turn gets the spectrum access as a reward for the cooperation. With only information cooperation between primary and secondary networks, we first provide the optimal resource allocation policy that maximizes the secondary user sum-throughput and address the issue of fairness at the user level. Then we consider the information as well as energy cooperation between primary and secondary networks over a finite horizon, where we show the improvement in rate regions due to this two-level cooperation. The second part of the thesis focuses on the underlay mode, where secondary users seek help from an intermediate node to facilitate their communication under the primary's interference constraint. We first analyze the outage performance of the secondary network with the cooperation from energy harvesting relays. Then we investigate the secure communication via an untrusted energy harvesting relay and provide design insights to obtain positive secrecy rate. Third, in a non-energy harvesting scenario, we perform outage analysis for the secondary network with direct-link assisted relaying under the primary's interference. The third part of the thesis focuses on the interweave mode. We first study conventional energy detection based cooperative spectrum sensing in the presence of malicious users that send falsified spectrum sensing data. We propose an outlier method based on Dixon's test to find a malicious user and remove it from the cooperation. We then consider an improved energy detection, where a positive power operation p replaces the squaring operation in conventional energy detection. We analyze its spectrum sensing performance with multiple antennas and study the effect of antenna correlation on the optimum value of p.

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Title : *InGaAsP/InP multi-quantum well Embedded ring Electro-optic or All-optical modulators, filters and switches*

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Supervisor : *Das Utpal*

Abstract

Coupled resonator rings, of one placed inside another is called embedded ring (ER) resonator, and show sharp resonances due to interfering modes of the individual rings. InGaAsP multiple quantum wells (MQWs) have strong electro-optic quantum confined stark effect (QCSE) and nonlinear effects and, can be integrated with diode lasers and photodetectors. InGaAsP MQW ERs can thus work as optical modulators and switches with improved speed, ease of integration and less power dissipation. A model has been developed to predict the linear and quadratic electro-optic coefficients, which in conjunction with transfer matrix model, Bessel function and vector coupled-mode theory, have been used to design the ER devices. New static and dynamic models have been developed, enabling m radius embedded ring tuneable filters and 20Gbpsμthe design of ~5 modulators. For an InGaAsP MQW, nonlinear refractive index (n2) of -3.82x10-12 cm2/W shows a 5G 8 bit packets/second path switching operation in the ER. Incorporating free carrier effects in the dynamic device model, it is observed that the carrier removal is enhanced for a reverse biased PIN heterostructure, and a 20Gbps optical path switch can be theoretically achieved. Electron beam lithography with proximity correction and Al lift-off etch mask for ~100nm feature size in ICP RIE m tall ER side walls.μetch process has been optimised, for obtaining 4.5 The mask lift-off induced corrugations on the sidewalls resulted in larger than expected losses due to energy transfer to higher order modes. Reduced side wall roughness using an improved Cr/SiO2 mask mμprocess has resulted in the demonstration of path switching in a ~5 radius ER and a good match with the theoretical model. Temperature and nonlinear tuning of the ER resonance has also been achieved using the fabricated device, which can be explored for future photonic applications.

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Title : Studies on Multi-band Linearly and Circularly Polarized Printed Antennas for Wireless Communication Systems

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Abstract

In this thesis, novel designs of multi-band linearly and circularly polarized printed antennas employing few unit cells of metamaterial are proposed. The sub-wavelength resonance property of the metamaterial resonators and phase lead behaviour of the Composite Right/Left handed transmission line (CRLH-TL) in the left handed band have been utilized to achieve miniaturized and multi-band functionality in conventional patch antenna and printed dipole antenna. Initially, a design of dual-band dually polarized patch antenna with circularly polarized (CP) radiation in the lower band and linearly polarized (LP) radiation in the higher band is proposed, which is realized by suitable embedding of a mushroom unit cell along the diagonal of a slotted patch antenna. Next, multi-band dipole designs with suitable loading of metamaterial unit cells are also discussed. In contrast to the phase lag nature of conventional TL, the phase lead behaviour of CRLH-TL unit cells is utilized to get multi-band operation in a printed dipole antenna. Loading of via-less CRLH-TL unit cells in both the arms of a conventional printed dipole antenna leads to a multi-band operation. Further studies confirm that the multi-band functionality in printed dipoles can be achieved by utilization of sub-wavelength resonances of the metamaterial resonators. Loading of the dipole arms with a single-band resonator provides a dual-band operation while the use of a dual-band resonator leads to a tri-band behaviour. The operating bands of the multi-band dipoles realized using CRLH-TL unit cells or use of resonators exhibit linearly polarized behaviour with omni-directional radiation pattern (rephrase). In order to obtain CP behaviour in the operating bands, a pair of the multi-band LP dipoles are placed orthogonally in crossed configuration and a vacant ring is used as phase delay line to provide a 90o phase difference between the dipole arms. The multi-band CP crossed dipoles have a narrow CP operating bandwidth and bi-directional pattern with low gain. It has been studied that the use of a cavity backed reflector of suitable dimension along with the multi-band CP crossed dipole is capable of enhancing the operating CP bandwidth and gain significantly compared to that achieved in free space. Multi-band pattern reconfigurable antennas are also designed by the use of parasitic copper strips with varying lengths on both sides of the resonators loaded multi-band LP printed dipole antenna. The multi-band pattern reconfigurable antenna is capable of steering the omni-directional radiation pattern of the driven element into broadside, bi-directional end-fire and uni-directional end-fire radiation patterns. Designs of dual-band and tri-band pattern reconfigurable antennas where the lengths of parasitic elements are controlled electronically using PIN diodes and Varactor diodes are also studied. The design principles of the proposed multi-band linearly and circularly polarized antennas have been validated by measurement carried out on their fabricated prototypes.

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Title : Intelligent Hybrid Classifiers for Real Time Applications
Author(s) : Sevakula Rahul Kumar
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Supervisor : Verma Nishchal Kumar

Abstract

Classification algorithms form the basis of decision making in most pattern recognition problems, e.g. image recognition, speech and speaker recognition, iris recognition, spam mail detection etc.. With the horizon of their applications expanding at a fast pace, the need for further research has only increased. This fact becomes particularly true because: a) each application poses its own set of challenges and b) one would always find a classifier with a particular improvisation that best suits the situation. Understanding the opportunities, this thesis aims to solve 4 independent problems that have great relevance for certain real time applications. The first part of the thesis focuses on dealing with class noise in Fuzzy Support Vector Machine (FSVM) classifier. FSVM is considered to be a significant addition over soft margin SVM like C-SVM, for the former can guard against outlier sensitivity and the latter cannot. The ability of FSVM to absorb outliers, strongly depends on how well the training samples are assigned fuzzy membership values (MVs). Traditionally, the membership functions (MFs) used for FSVM were custom made for applications, and MFs used for one could in general not be used for others. To overcome the limitation, General Purpose Membership Functions (GPMFs) are defined in this thesis as those MFs which can universally be used for multiple applications, and which allow FSVM to statistically perform better than C-SVM. The thesis contributes to GPMF literature in two stages. Firstly with help of convex hulls, it presents few limitations that FSVM faces while treating all samples of a class with a single MF. Further, it recommends differential treatment to data by categorizing them into two fuzzy sets: one containing possible non-outliers and other containing possible outliers. While possible outliers are modelled with a normal MF, possible non-outliers are recommended to have a constant MV of '1'. The chapter then introduces novel GPMFs which use clustering based techniques to detect possible outliers, and use Hausdorff Distance and pt-set to characterize those possible outliers. To establish conclusions, the introduced GPMFs are thoroughly evaluated and statistically compared with earlier GPMFs on numerous real world benchmark datasets. The results show that vi proposed GPMFs not only perform significantly better in treating class noise, but also execute with efficient run time complexity. In the second part of the thesis, a novel scheme to introduce deep learning in Fuzzy Rule based classifiers (FRCs) is presented. FRCs have gained prominence for their unique ability of giving good classification performance, and allowing existing expert knowledge to be used conjointly with training data. Recent innovations in Deep Neural Networks are allowing researchers to tackle some very complex problems with improved theoretical and empirical justifications e.g. image classification, audio classification. The thesis presents a scheme to incorporate stacked denoising sparse auto-encoders within the FRC framework. While stacking of denoising sparse auto-encoders help learn the complex non-linear relationships amongst data and represent the input data in a reduced compact feature space, the framework built towards FRC allows users to input expert knowledge to the system. To make denoising sparse auto-encoders learn more effectively, data pre-processing strategies have been proposed. Further, to improve the classification performance and rule reduction performance of the FRC, three fine tuning strategies have also been proposed. The proposed framework is tested across real world benchmark datasets, and elaborate comparison across literature shows that proposed methods are capable of building FRCs that provide state of the art accuracies and/or few rules, as per the user's demand. The third part of the thesis aims at finding classifiers which exhibit extremely low variance. Classification algorithms are traditionally designed to simultaneously reduce errors caused by bias as well by variance. In many situations, low variance becomes extremely crucial for getting tangible classification solutions and even slight overfitting can have serious consequences in the test results. Classifiers with low variance have two main advantages: 1) the classifier statistically manages to keep the test errors close to the training error, and 2) the classifier learns effectively

even with small number of samples. The thesis introduces a class of classifiers called Majority Vote Point (MVP) classifier, which on account of lower Vapnik Chervonenkis (VC) dimension has lower variance than even linear classifiers. The thesis contributes by estimating a trend for MVP classifier's VC dimension, and validates its low variance on two real time problems. vii The thesis finally focuses on the real time application of condition based monitoring of machines using acoustic and vibration measurements. Signal data acquired from machines, are often found to change with time, wear and tear, and subsequent repair of the machine. Classifiers are typically trained to perform the decision making procedure during fault diagnosis/detection. Since data may change with time; low generalization error is essential to avoid overfitting during classification. Therefore MVP classifier is seen to be best suited for this situation. However, MVP classifier has a limitation that it may not be able to fit data sufficiently, and can lead to high training error. The thesis presents a novel framework for pattern recognition, where novel procedures for optimal data source (sensitive position) identification, data acquisition and feature selection are tailored to give best possible training performance with MVP classifier. The understanding here is that if MVP gives low training error, real time fault diagnosis of machines becomes feasible with consistent accuracy. The introduced framework was experimentally implemented and tested for an air compressor condition monitoring application; associated real time experiments showed a significant improvement in reliability of fault detection.

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Title : ***Algorithms For Reliability In Large Scale Structured And Unstructured Peer-To-Peer Overlay Multicast Networks For Live Streaming***

Author(s) : ***Singh Ashutosh***

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Supervisor : ***Singh Yatindra Nath***

Abstract

Exponential growth in the reach of internet among people and the advent of peer-to-peer (P2P) technology has revolutionized the way of human interaction in last two decades. P2P technology, that initially came up with an aim to optimize resource sharing among systems in the network gave birth to many interesting applications. P2P network can support multicast also called as Application Layer Multicast (ALM) to millions of people distributed across the globe. ALM has been proven a good alternate of IP (network layer) Multicast where multicast-related functionalities are moved to end-hosts. In ALM, peers self organize themselves and an overlay topology is built for data distribution. Either we take structured or unstructured P2P network as substrate, the major concern in ALM is to route data efficiently and reliably in the overlay topology. This thesis is an attempt to provide solutions to the related issues. We start with taking up unstructured P2P network and propose an overlay tree construction and maintenance scheme in which a mesh-like topology is first built, on top of which data delivery tree(s) are built. In the formation of mesh, it is ensured that two node and link disjoint paths are always maintained between every possible pair of nodes. In the data distribution tree, each node maintains two neighbouring nodes which provide the two best paths toward the source. The case of structured P2P networks is taken up next, where availability of query search network like Distributed Hash Table (DHT) based look up service is assumed. Three variants of dual-feed data distribution scheme are proposed. This enables building of multicast tree directly as an overlay. It is observed with simulation results that the proposed scheme yields the expected results even at high failure rates. Further the issue of flash crowd that rises during high network growth rate in the beginning of a session is considered. Two different algorithms, one to alleviate the load of root nodes and other to guarantee the provision of feed to any arriving node even at very high growth rate are proposed. The simulation of proposed algorithms on a Chord based overlaid multicast system proves their effectiveness.

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Title : Modeling of Substrate Depletion, Self-heating, Noise and High Frequency Effects in Fully Depleted SOI MOSFETs

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Abstract

In order to facilitate high performance at low power consumption, the MOSFET size is shrinking continuously. In sub-micron technology regime, the bulk MOSFET has started facing severe short channel effects and excessive power dissipation. To overcome these challenges, different architectures (Fully depleted silicon on insulator and FinFET) and different channel materials (MoS2, III-V and Graphene) are gaining momentum as viable options. In advanced silicon nodes, fully depleted silicon on insulator (FD-SOI) and FinFET are two main competitors. FD-SOI is a planar structure device, like the bulk MOSFET and it reduces manufacturing complexities in comparison to non-planar structures (FinFET). It offers several additional features as compared to the bulk MOSFETs: (i) complete dielectric isolation from the substrate, resulting in lower junction leakage, capacitance, and latch-up immunity; (ii) lightly doped/undoped silicon body provides immunity against the process induced variations; (iii) ultra-thin buried oxide (BOX) enables threshold voltage tuning via back gate; (iv) the use of different work-function metal gates and substrate doping allow to achieve multi-threshold flavor on a single chip. An accurate and computationally efficient compact model is required to simulate circuits prior to the real device fabrication. Developing a compact model for FD-SOI MOSFETs is a challenging task, due to the presence of two non-symmetric interfaces and their independent bias conditions. Coupling between front and back gates makes the surface potential and mobility calculations more complex. Furthermore, FD-SOI MOSFET faces carrier fluctuations from both the interfaces which affect various device properties, especially for different backbias conditions. For example, carrier mobility and channel noise are dependent on interface quality and therefore, conventional bulk MOSFET based models may not be valid for FD-SOI MOSFETs. Another advantage of FD-SOI MOSFET includes threshold voltage tuning facility through back-bias. However, some fraction of the applied back-gate bias drops in the substrate region, thereby changing the effective back-bias and threshold voltage shifts. Also, the SOI MOSFETs are more prone to self-heating due to the presence of BOX below the channel, since SiO2 has lower thermal conductivity as compared to silicon material. FD-SOI MOSFETs with high resistivity substrate are also attracting the radio frequency (RF) circuit designers for high-frequency applications. However, at high frequencies, the device characteristics have frequency dependence via several inherent phenomena, like self-heating effect, substrate effect, and gate resistance effect. For example, the substrate resistance-induced thermal noise gets coupled with the channel noise at high frequencies. Thus, DC compact model is not sufficient to predict correct device behavior observed from measured data over a wide frequency range. For a robust compact model, it is important to capture all such real device effects. In this thesis, we attempt to investigate and model some of the above issues. The proposed models are developed within the framework of the BSIM-IMG model, which is the latest industry standard surface potential based model for FD-SOI MOSFETs. The thesis is organized into eight chapters as follows: In Chapter 1, we discuss the challenges involved in CMOS scaling and also discuss the available solutions for it, beyond 20 nm gate lengths. Benefits inherent with FD-SOI MOSFET's architecture are discussed in detail along with the discussion on current market survey. Then we explain the need of compact models and finally, the basic flow chart of the BSIM-IMG model's working is presented. In Chapter

2, the non-physical capacitance behavior in the BSIM-IMG 102.0 model is discussed. The origin of the issue was the assumption of constant displacement field at the back interface, while calculating the initial guess for the front gate surface potential. In this chapter, we propose the improved surface potential calculation for the independent double gate MOSFETs. The improved model is implemented in the BSIM-IMG 102.5 model, which shows distinctive improvement over BSIM-IMG 102.0 model. The model shows accurate behavior for C-V and I-V characteristics, while keeping smooth behavior for their higher order derivatives. In independent double gate MOSFETs, the vertical electric field changes its sign according to the front and back gate biases, which result in a non-unique relationship between electric field and carrier distribution. In this chapter, we also develop an effective mobility model for a wide range of back gate biases, solely dependent on technology parameters. This effective mobility model allows the user to predict the deviation in device characteristics due to the variations in the device structure. The model has shown good agreement with the measured data obtained from CEA-LETI as well as with the data reported earlier in literature. UTB-SOI MOSFETs are famous for their threshold voltage tuning facility through backbias. Some fraction of this applied back-bias drops in the substrate region below the BOX, which depletes the substrate. In Chapter 3, we discuss the impact of substrate depletion on device characteristics. We have proposed an approach to include the effect of substrate depletion in a surface potential based compact model for UTB-SOI MOSFETs. The proposed model is extensively verified for both NMOS and PMOS with geometrical and temperature scaling. Model validation is done at 50 nm technology node with the state of the art UTB-SOI MOSFETs provided by Low-power Electronics Association and Project (LEAP) and excellent agreement with the experimental data is achieved. Chapter 4 begins with a discussion on self-heating effect in FD-SOI MOSFETs. Higher device heating in this MOSFET results in higher thermal resistance. From 3D TCAD simulations, we observed that device thermal resistance increases further with the reduction in channel length. The impact of geometrical scaling on the thermal resistance is investigated in this chapter. A new behavioral model to capture geometrical scalability of thermal resistance is proposed and validated against the TCAD and experimental data. Chapter 5 explains that the flicker noise behavior in independent double gate MOSFETs is different from bulk MOSFETs, due to presence of different interface qualities and bias conditions at front and back gates, respectively. Thus, a flicker noise model dedicated to FD-SOI MOSFETs, which can capture device behavior accurately from weak to strong inversion regions is required. In this chapter, we have developed a physics-based unified flicker noise model for independent double gate MOSFETs. This model predicts correct flicker noise behavior for a wide range of the front and back gate biases. The model is validated against noise measurement data from 1 Hz to 65 kHz. The proposed model is computationally efficient and implementable in any SPICE model for circuit simulations. In Chapter 6, we first discuss the RF properties of the FD-SOI MOSFETs. A new RF model capturing all the high-frequency effects is proposed. Step-by-step parameter extraction methodology of the BSIM-IMG model is also proposed and validated against the measured Sparameter data. The model is validated over a wide range of biases and frequencies, and shows excellent agreement with the experimental data. Chapter 7 contains the noise measurements for ultra-thin body and thin buried oxide (UTBB) FD-SOI MOSFETs in the RF frequency range. We analyze the impact of front and back gate biases on thermal noise behavior, along with the discussions on the secondary effects in FDSOI MOSFETs, which contribute to the thermal noise. Using calibrated TCAD simulations, we show that the noise figure changes with the substrate doping and buried oxide thickness. Finally, Chapter 8 summarizes the research work carried out in this thesis and also suggests the scope of future work in this area.

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Title : Modeling of Drain Current, Transconductance and Flicker Noise in Presence of Doping Non-Uniformity

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Abstract

Compact models are an important part of the Process Design Kit (commonly known as PDK), which is the interface between circuit designers and foundries. A good compact model must accurately capture all the real device effects, and at the same time, it should produce them in a form suitable for maintaining high computational efficiency. BSIM4 is a very celebrated and popular model among the device and circuit designer community, and is used even for advanced nodes (for e.g. 28nm). However, analog and RF designers have complained about a subtle but important issue of asymmetry around Vds = 0V, whose origin lies in several places such as BSIM's threshold voltage based core, implementation of bias dependent effects, etc. To address asymmetry issue and to capture advanced CMOS effects, a new compact MOS model BSIM6 is developed. BSIM6 was declared industry standard in 2013 after rigorous testing by the companies under the umbrella of Compact Model Coalition (CMC).State of the art CMOS process makes use of halo implants. In halo implantation process, two highly doped pocket regions are created near the source and the drain regions. This limits the extension of the source/drain depletion width into the channel, and increases the gate control. A good compact model is supposed to capture all the effects of such process enhancements. For e.g., halo implants have significant impact on various aspects of device performance, e.g. transconductance (gm), output conductance, drain induced threshold shift (DITS), low frequency (1/f) noise, etc. While output conductance degradation and DITS effects are well understood in the literature, the impact on gm and 1/f noise behavior need more understanding. Halo devices carry high on-current as compared to the uniformly doped (UD) devices with same threshold voltage. Therefore, if one measures gm in the linear region, it comes out that the peak gm of the halo device is higher than that of the UD. Since gm is an indicator of mobility, this directly leads to the conclusion that carrier mobility in the Halo device is higher as compared to UD devices. This is against the intuition, since the highly doped pocket regions should either decrease effective mobility or at best, it should not have any impact because of their short length. This is indeed true, thanks to mobility extracted from split CV measurements. Therefore, it is established that gm is no more an indicative of effective mobility in lateral non uniformly doped devices and this is termed as mobility artefact. Fig. 1(a) illustrates the impact of halo implants on gm through TCAD simulations. The mobility degradation model is turned off to elucidate the explicit impact of the doping non-uniformity. It is clearly observed that halo implants introduce peaking transconductance behavior Doping non-uniformity also results in unconventional 1/f noise properties. Low frequency noise has been critical in sub-micron technology, both for analog and digital designs. Equivalent threshold voltage variation due to Random Telegraphic Noise exceeds the threshold voltage variation due to the random dopant fluctuation in 22nm technology node, posing a real challenge to device stability. We investigate the two cases of doping non-uniformity: first, where the entire channel (from source to drain) is non-uniformly doped, and second is the case of Halo implants. The halo implantation process introduces additional traps in the halo regions, which are activated only in particular bias conditions and therefore, leads to peculiar bias dependency. Therefore, the noise models based on uniform channel assumption are not valid. This is illustrated in Fig. 1(b), which shows the power spectral density of drain current noise (SID) of a MOS with lateral erfc doping profile. It can be observed that the very popular unified model of 1/f noise cannot model typical noise behavior. The insight gained from the analysis (and modeling) of the first case is utilized to develop a compact model for the second

case. In this thesis, we also present a compact model of threshold voltage (Vth) within the framework of charge based model. State of the art modeling approaches (surface potential/charge based modeling) do not endorse threshold voltage based methodologies and, therefore Vth, is not explicitly available in such models. It is, however, necessary to know Vth of the transistor, because circuit designers require it to bias the circuit in appropriate region, e.g. analog designer uses it to bias the transistor in saturation region and digital designer needs it to determine on current. We develop an analytical model of threshold voltage, which is based on the condition of Idrift = Idiffusion and which can be used for operating point information in SPICE engines. The proposed model is implemented in the BSIM6 MOS model and is available in the public domain.

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Title : Advanced Resonant Sensors for Microwave Characterization of Materials and Their Applications

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Abstract

Accurate measurement of the electromagnetic (EM) properties of materials at radio frequency (RF) and microwave frequency is considered to be the grey area of research. The proposed research work discusses advancement in the conventional resonant methods, and generalization of the approach for precise testing of the dielectric, magnetic, magnetodielectric, and composite samples in the solid, liquid, and granular forms. This study is based on the effort to make the resonant method applicable for the characterization of materials with higher permittivity and permeability, lossy materials and samples having electrically large dimensions. In this thesis, an attempt is made to relax some of the major assumptions of the conventional cavity perturbation technique to get more accurate EM properties of material under test (MUT). First of all, the finite volume of the test sample, which was usually neglected in earlier formulations, is taken into consideration. The sinusoidal EM field variation over the geometry of the MUT is also considered, and accordingly, the improved closed-form expressions are established using the first principle. The proposed new sets of closed-form expressions are capable of providing accurate results than the conventional techniques even for electrically larger samples. The improvised analytical expressions are then used in conjunction with the developed optimization scheme. The unique optimization scheme facilitates the exemption of another assumption viz. the cavity being made of PEC, and considers the effect of the sample holder and the presence of practical air gap between the MUT and the cavity. The proposed unified approach is made fully automated to solve the problem in limited time frame with a typical accuracy of 97-98%. In the next step, the measurement of complex permittivity and complex permeability of arbitrary length samples, which is quite challenging due to various limitations of the conventional approach, is discussed in detail. The complete EM analysis is proposed for testing of arbitrary length samples, which considers the depolarization effect, the demagnetization effect, the image theory analysis, and the non-uniform EM field over the MUT. The proposed technique involves novel formulae for measurement of arbitrary length samples that are accordingly derived and numerically verified. The advantage of newly derived formulas can be appreciated due to their excellent accuracy typically more than 98% for samples having their length less than 0.5 times the width of the RC. After improving the rectangular waveguide based cavity technique, the proposed technique is applied to the planar RF sensors, which are setting new trends in the microwave industry. To this end, the substrate integrated waveguide technology is first used to design and develop the compact RF sensors in order to characterize dielectric materials. Thereafter, a new kind of SIW cavity based epsilon-near-zero (ENZ) planar sensor is proposed to characterize dielectrics and composites in solid, liquid, and granular form. The novel multichannel ENZ sensor is unique in its design, which not only makes the overall testing system to be quite compact but also makes the microwave material testing to be feasible at more than one frequency, with the device being operated in the same mode. Due to the high sensitivity of the developed resonant sensors, they have the capability to detect even a small amount of adulteration in base products. From the application point of view, the proposed RF sensors have been employed to detect the adulteration level in various edible fluids and petrochemicals. The developed sensors can also be used for microwave imaging due to their fine sensitivity in measurement. They can play a major role at the front end of various microwave material processing industries and are most suitable for various applications in humanitarian technology. The proposed advanced measurement techniques have also got potential applications in the areas of microwave material engineering; high-speed electronics; remote sensing; physical, chemical, and biological sciences.

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Title : ***StudiesonSubstrateIntegratedWaveguidebasedFilters, Multiplexers,LowPhaseNoise Oscillators and their application to Planar Transceiver Design***

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Supervisor : ***Biswas Animesh***

Abstract

With the rapid growth in the modern wireless communication system, compact and efficient wireless components are indispensible. The transmission and radiation losses in microstrip and coplanar waveguide prevents their use at higher frequency band. Recently, Substrate Integrated Waveguide (SIW) was introduced and became popular choice among researchers. It has advantages of both waveguide (non-planar) as well as conventional planar technologies (e.g. moicrostrip, co-planar waveguide etc.) such as low loss, high Q, good electromagnetic shielding, easy interconnections etc. The most significant advantage of SIW technology is the possibility to integrate all the components on the same substrate, including passive components, active elements and even antennas. A study on single and dual mode filters realized in SIW platform is discussed along with its design principle. This working principle of the filter are also extensively used in realizing multiplexer (Diplexer, Triplexer) with the help of filter theory. With the advancement of communication systems, high performance bandstop filter's requirement are in growing demand because of its application in suppressing noise and interference signals over specific bandwidth. Single and dual-band bandstop filters are realized using filter theory and coupling topology. Balun filter is also one of the attractive candidate of modern wireless communication system that not only converts an unbalanced signal to balance one but also improves frequency selectivity of the balun because of filtering characteristic. SIW based balun filter and diplexer are realized using filter theory and its design techniques are explained in the thesis. Recently, the concept of filtering antenna is evolving. The design purpose and process of the filtering antenna are fairly different from those of the conventional antenna. The filtering antenna is not merely another impedance matching approach, but also a shaping for a filter-like frequency response both for antenna gain (corresponding to insertion loss in filter terminology) and input return loss. In the thesis, cavity backed slot antenna is adopted as an antenna integrated with SIW based dual-mode filter. These integrated filter, diplexer, triplexer antennas are designed using cavity backed slot antenna with the help of filter theory and coupling topology. Further research works are carried out in designing low phase noise feedback oscillator where high Q and sharp frequency selective characteristic of SIW based bandpass filter helps in reducing phase noise. The application of dual-mode SIW based filter, low phase noise oscillator and diplexeing antenna are presented in designing Self-Oscillating Mixer (SOM) and Voltage controlled Active Integrated Antenna (AIA) which are used as receiving and transmitting section respectively. Both transmitting and receiving sections are integrated with diplexeing antenna on the same substrate and therefore, it brings compactness in the transceiver design. The transceiver systems are design for X-band application. The research work presents a detailed study on several design methodologies to enhance performance of high frequency microwave passive and active systems. The use of SIW technology makes the designs advantageous for using in high frequency microwave applications. All the proposed designs are validated by experimental results and detailed analysis of the proposed designs are also developed.

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Title : ***Frequency Shift Free Optical Phase Conjugation and its Applications to Coherent Optical Communications***

Author(s) : ***Anchal Abhishek***

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Supervisor : ***Krishnamurthy Pradeep Kumar***

Abstract

In the last decade, coherent optical communications combined with digital signal processing has emerged as the technology for high data rate (beyond 100 Gbps) and long distance communications. One of the main challenges in high data rate coherent optical communication systems is to increase the launch power without incurring significant penalties due to fiber nonlinearities. Mid-span spectral inversion (MSSI) and phase-sensitive amplification (PSA) are examples of all-optical techniques that are being investigated for their potential to compensate for fiber impairments and nonlinear phase noise respectively. Both of these techniques can be implemented using optical phase conjugation (OPC) due to its transparency to modulation formats. OPC is usually generated by four-wave mixing (FWM) interaction in fiber or semiconductor optical amplifiers in which the idler is phase conjugate of signal. The generation of idler is usually accompanied by a shift in frequency leading to strong channel crosstalk in WDM systems. In this research, we have developed a method of frequency-shift free OPC using counter-propagating dual pumped FWM in fiber. The two counter-propagating pumps interact with signal inside fiber to create two gratings. The two pump waves diffracts from the grating to generate a backward propagating idler wave whose phase is conjugate of signal phase. By placing the pump frequencies symmetrically about signal frequency, we ensure that the idler has the same frequency as that of the signal. Since the signal and idler waves appear at opposite ends, the idler is easily filtered out from the rest of the spectrum. Ideal phase conjugation is achieved at an optimum length of fiber for a given pump power. A detailed study of effect of critical design parameters such as fiber length, pump power, and detuning between pump and signal on conjugate efficiency and phase-offset has been carried out. We experimentally verified our phase-conjugation technique in C-band by counter-propagating dual pumped non-degenerate FWM in SOA. In contrast to fiber case, frequency-shift free operation cannot be achieved in SOAs due to end facet reflectivity. We have demonstrated FWM conversion efficiency of 1%, which is 5-times higher than previously reported value. For the first time, in our knowledge, we directly demonstrated the spectral inversion by OPC using time-resolved chirp measurement of electric field envelope of signal and conjugate waves. We examined the performance of frequency-shift free OPC as MSSI and PSA elements for mitigation of nonlinear effects and nonlinear phase noise, respectively in standard single mode fiber (SSMF). By numerical simulations, we demonstrate near complete nonlinearity mitigation of 40 Gbps DQPSK modulated data transmitted over 1000 km SSMF using our proposed OPC. We have shown analytical that PSA employing frequency-shift free OPC has 0 dB noise-figure with high gain-extension ratio. Simulation results show that PSA output is forced to attain 0 or π phase regardless of large variation of phase in input signal. Nonlinear phase noise reduction of 40 Gbps DPSK signal transmitted over 1000 km SSMF confirmed the phase-regeneration by PSA. In conclusion, we proposed a novel technique for frequency-shift free OPC in fiber and demonstrated experimentally in SOA using counter-propagating dual pumped FWM process. We also verified that our OPC technique can be used as MSSI to mitigate nonlinear effects of fiber and as PSA for phase-regeneration of DPSK signals.

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Title : Compact modeling of capacitance and current in silicon and iii-v transistors

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Abstract

As the CMOS scaling continues, at advanced technology nodes, (i) improved electrostatic control and (ii) superior transport properties are desired to have better control on short channel effects and to achieve required drive current, respectively. The thin body multigate devices with alternative channel materials provide better electrostatics control along with superior transport properties. In alternative channel materials, group III-V materials are being looked upon as promising options for the digital (e.g. InAS, InGaAs, InSb etc.) as well as the RF and high power applications (e.g. GaN, AlGaN, GaAs etc.) owing to the suitable material properties, obtained from combination of materials from both the groups. Presently, Si-based devices which are the driving force of semiconductor industry face undesirable effect such as sub-band gap impact ionization with scaling of channel length. Hence this thesis work is focused on addressing both (i) alternative options for future technology nodes and (ii) improvements in currently used Si-based devices. The main objectives of this thesis are to investigate III-V materials as alternative channel material, in thin body devices, through the numerical simulation study and development of analytical/compact models. The thesis also presents unified impact ionization model for Si based nano-scale MOSFETs including sub-band gap (thermally assisted) impact ionization and conventional channel field assisted impact ionization. The work presented in this thesis is organized as follows: ♣ Simulation study of back gate bias effect on gate capacitance and threshold voltage for III-V channel FETs – Numerical simulation study using self-consistent solution of Poisson-Schrodinger equation is presented for gate capacitance and threshold voltage for InAs channel ultra-thin body with thin back gate oxide (UTBB) devices. The simulation study shows the effect of quantum capacitance induced by low density of states and contribution of multiple sub-bands on the gate capacitance. ♣ Modeling of charge density, capacitance and drain current for III-V channel FinFETs and Quadruple gate FETs for digital applications – Compact model of charge density, capacitance and drain current is proposed for III-V channel FinFET and Quadruple Gate FETs considering the effect of low density of states (DOS). The proposed models include the effect of low DOS induced quantum capacitance and contribution of multiple sub-bands. ♣ Modeling of threshold voltage and drain current for GaN based FinFETs/tri-gate FETs for power switching applications – A behavioral model of threshold voltage and drain current for normally-off (enhancement mode) AlGaN/GaN based tri-gate HEMT is presented. ♣ Unified impact ionization model for silicon channel based RF SOI MOSFETs – A unified model of impact ionization effect for SOI MOSFETs is proposed and implemented in BSIMSOI to validate the model with experimental data. Proposed model captures the physics of sub-band gap (thermally assisted) impact ionization along with the conventional (channel field assisted) impact ionization.

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Title : Robust Spectrum Sensing for Multiple-Input Multiple-Output (MIMO) Cognitive Radio Networks

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Supervisor : Jagannatham Aditya K

Abstract

This thesis addresses the problem of spectral hole detection in cognitive radio networks (CRNs) considering uncertainty in the estimate of the channel state information (CSI)/covariance statistics. After introduction, two chapters of the thesis present single secondary user based robust spectrum sensing techniques whereas the succeeding two chapters focus to develop multiple secondary user based robust spectrum sensing schemes towards spectral hole detection in Multiple-Input Multiple-Output (MIMO) CRNs, under the CSI/covariance statistics uncertainty. First, we introduce novel detection schemes which are robust with respect to the uncertainty in the estimate of the signal covariance matrix for non-coherent spectrum sensing in MIMO CRNs. We employ an eigenvalue perturbation theory based approach to model the uncertainty in the estimated signal covariance matrix. Subsequently, we derive an optimization framework for the generalized likelihood ratio test (GLRT) based robust test statistic detector (RTSD) and robust estimator-correlator (EC) detector towards primary user detection, which incorporate the CSI uncertainty inherent in such scenarios. Further, employing the Karush-Kuhn-Tucker (KKT) conditions, we derive closed form expressions for the proposed robust spectrum sensing schemes. Further, we develop GLRT-based detectors for robust spectrum sensing in MIMO CRNs considering unbounded uncertainty in the available CSI. Initially, for a scenario with known CSI uncertainty statistics, we derive the novel robust estimator-correlator detector (RECD) and the robust generalized likelihood detector (RGLD), which are robust against the uncertainty in the available estimates of the channel coefficients. Subsequently, for a scenario with unknown CSI uncertainty statistics, we develop a GLRTbased composite hypothesis robust detector (CHRD) for spectrum sensing. Closed form expressions are presented for the probability of detection and false alarm to characterize the detection performance of the proposed robust spectrum sensing schemes. Further, a deflection coefficient based optimization framework is also developed and solved to derive closed form expressions for the optimal beacon sequences. Next, we present novel detection schemes for non-antipodal signaling based cooperative spectrum sensing (CSS) in MIMO CRNs, which are robust against the uncertainty in channel estimates. We formulate this problem employing the optimal linear discriminant and model the uncertainties in the CSI as ellipsoidal uncertainty sets. It is then demonstrated that this problem of primary user detection with uncertainty in the channel estimates for CSS in a CR system can be formulated as second order cone program (SOCP). Further, we extend this paradigm to the associated relaxed and multicriterion robust detectors that maximally separate the hypothesis ellipsoids in low signal-to-noise power (SNR) and deep fade channel conditions. We also present closed form solution for the proposed robust detector. The final part of the thesis presents various schemes and the associated performance analysis for CSS in MIMO CRNs considering also uncertainty in the CSI of the secondary user channels available at the fusion center. The proposed schemes employ cooperative decision rules based on local sensor decisions transmitted to the fusion center. To begin with, fusion rules are derived for the scenario under perfect CSI at the fusion center for both antipodal and non-antipodal signaling. Then, a robust detector, termed the US-LRT, which optimally combines the decisions of the different secondary users, is obtained for CSS in MIMO CRNs under CSI uncertainty. A GLRT based robust detector is also derived for a similar setting. Closed form expressions are obtained to characterize the probabilities of false alarm and detection at the fusion center for the proposed schemes.

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Title : Non-Convex Optimization over Networks
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Supervisor : Rajawat Ketan

Abstract

Networks are ubiquitous, and they arise at various levels and scales, such as communication networks, power networks, social networks, internet, robotic networks, and sensor networks. Tasks e.g. estimation, resource allocation, inference, learning, and control over networks are often formulated as convex or non-convex optimization problems. Optimization method over networks are dictated by various requirements and constraints. Assorted constraints like spatially distributed nodes, heterogeneity of nodes and locally observable objective functions, necessitate the algorithm to be distributed and tolerant to delay and asynchrony. Additionally time-varying network topology and random channel environment, often cause uncertainties in the information flow and the objective function. Thus it require for an algorithm to be robust against such uncertainties for decision making. Thereby, these requirements complicate the design and analysis of algorithms significantly and necessitating novel and innovative approaches. Distributed algorithms for solving network-wide convex optimization problems have been well-studied in the last two decades. However, the performance of these algorithms for non-convex problems have not been properly characterized, since establishing convergence guarantee for the non-convex problems with multiple local minima are analytically rigor. Important application areas where such non-convex problems arise naturally, include cooperative localization, matrix factorization, sparse estimation, distributed demodulation, interference alignment, network beamforming, and distributed power control. Under the rubric of non-convex optimization over networks, in the present thesis we have developed various provably convergent algorithms for a range of non-convex applications. The algorithms utilize alternating directions method of multipliers and majorization-minimization frameworks. The algorithms are computationally efficient, robust against uncertainties, tolerant to delay and asynchrony, easy to implement and scalable. The algorithms find application in asynchronous, dynamic and large scale network localization, distributed interference alignment, sparse principal component analysis, and dynamic network visualization.

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Title : Dynamic Analysis and Performance Improvement of Optimal EnergyHarvesting Methods for Variable Speed Wind Turbines

Author(s) : Yenduri Kalyan
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Supervisor : Sensarma Partha Sarathi

Abstract

Wind electric systems have progressed from fixed speed to variable speed wind turbines over the years. The principal appeal of Variable Speed Wind Turbine (VSWT) is higher energy yield along with other advantages such as reduced mechanical loads and noise levels. The VSWT extracts maximum power from the incoming wind when its tip speed ratio is maintained constant and equal to an optimal value. This necessitates changing its rotational speed according to the incoming wind speed variations. Maximum Power Point Tracking (MPPT) algorithm enables this operation, making it an essential feature of VSWT. Performance of the MPPT algorithm is therefore of paramount importance for maximizing energy harvesting capability of the turbine. Numerous MPPT algorithms have been developed and reported in the literature, considering the availability of various combinations of system parameters and measurements for their operation. Optimum torque (OT)-based MPPT is widely used in high power turbines because of its simplicity. Several recent improvements of this method claim better response speeds by augmenting the basic OT reference with a suitably scaled inertial torque. However, the underlying dynamic model for all these improved methods is premised on a rigid shaft, which ignores all torsional behavior. This lacuna is addressed in this thesis, where a small-signal model of the wind electric system including MPPT law is developed considering a more accurate flexible shaft model. It is shown that the improvements over OT MPPT could possibly have three distinct forms, the third being proposed in this thesis. Close-loop stability with each of these is analytically investigated using this accurate small-signal model. It is also proved that one of the reported approaches causes system instability while attempting even moderate improvement over the OT method. The problems in realization of the other two forms are highlighted and a realizable alternative proposed, which requires no additional sensor. Design of the proposed approach is presented in appropriate detail. It is analytically established that the proposed method ensures superior dynamic response, which is verified by numerical simulation. MPPT algorithms based on Hill Climb Searching (HCS) or Perturb-Observe method, well known from solar photovoltaic systems, are widely used in small to medium size wind electric systems. They use neither wind speed sensor nor turbine aerodynamic parameters. These are adaptable to parameter variation caused by aging and do not need regular tuning during operating life. HCS adjusts the reference command for the control variable, typically generator speed, in discrete steps at regularly spaced time instants, based on the measured variation in extracted power over the previous interval. But this algorithm suffers from the disadvantages of slow and deteriorated response under varying wind speed conditions. In this thesis, a comprehensive analysis of the torque transients in conventional HCS algorithm is presented. It is analytically shown in the thesis that improving the response speed of algorithm results in large torque transients in each sampling interval. This results in large current transients and obligates higher converter rating. Based on this analysis, two new alternative control schemes are proposed which significantly improve the response speed of the MPP tracking compared to conventional HCS. This is achieved while keeping the rating of the machine side converter same as in case of conventional HCS. A laboratory prototype of a 5kW Permanent Magnet Synchronous Generator based wind system is developed and the analytical results are validated both by numerical simulations and experimental results. The proposed schemes are also shown to perform better than the conventional HCS under the turbulent wind conditions.

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Title : *Global Peer Ranking Methods to Handle the Malicious Peers and Free-Riders in Peer-to-Peer Networks*

Author(s) : *Awasthi Sateesh Kumar*
Roll No : *13104186*
Supervisor : *Singh Yatindra Nath*

Abstract

Synopsis Name of the Student : Roll Number : Degree for which submitted : Department : Thesis Title : Thesis Supervisor : Month and year of submission : Sateesh Kumar Awasthi 13104186 Ph.D. Electrical Engineering Global Peer Ranking Methods to Handle the Malicious Peers and Free-Riders in Peer-to-Peer Networks Dr. Yatindra Nath Singh March, 2017 The peer-to-peer (P2P) networks leads to a significant amount of traffic on Internet due to its inherent advantages over traditional client-server networks, viz., scalability, robustness and diversity of data. On one hand, its open and anonymous environment gives everyone an opportunity to interact with the others, at the same time, it also brings new security threats. The malicious peers or the peers having conflict of interest can easily put inauthentic contents in the network. This can easily sabotage the system. Further, lacks of central control may lead to the problem of free-riding, i.e., peers download the resources without contributing anything to the networks. This leads the large difference between upload and download amount of resources in the peers. In such a situation, downloading speed for non-free-riders becomes very slow. Thus, efficient methods and policies to discourage the malicious and free-rider peers are needed. Maintaining the reputation system could be one of the methods to handle the malicious peers. This method has been studied by many researchers [1], [2], [3] in past. In this method, each peer evaluates the other peers and assigns them some trust value called local trust. These local trust values need to be aggregated in the network. The aggregated local trust is called global trust. The global trust is understood to be the trust, the system as a whole keeps on a peer. This is also called reputation of the peer. For the convergence of aggregation, local trust matrix needs to be stochastic, which requires the normalization of local trust. The process of aggregation of local trust is motivated by Google's PageRank [4] algorithm which is based on the popularity of page on the web. But, trustworthiness and popularity are different notions. In this thesis, we examine the problems with normalization of local trust and proposed a new algorithm, 'Absolute trust' to resolve them. The Absolute trust can rank the peers according to their trustworthiness and can also give their absolute characterization. We proved that the global trust vector will always converge at a certain unique value. Free-riding can be avoided by implementing an incentive mechanism. For this purpose, many incentive methods [5], [6], [7], [8], [9], [10], have been proposed in recent years. Among these, global approaches are considered better, because peers' cooperation is considered in the whole network. But implementation of a global approach is not trivial. To make the implementation simpler, we proposed a light-weight algorithm based on Biased Contribution Index (BCI). The BCI converge faster than the other existing global incentive mechanism. The BCI is also able to balance the upload and download amount of resources for each peer. The global incentive mechanisms are based on the iterative calculation of contribution index. We analyzed the problems with iterative calculation and proposed simplified form of BCI named SBCI. The SBCI is very simple to implement in a network. We also proposed and simulated the peer selection method based on well known 'the stability of marriage problem' [11]. Based on the above, the thesis has been organized in the following seven chapters. Chapter 1, defines the brief history and introduction of Internet and P2P networks. The classification of P2P networks based on central dependency and overlay network has also been discussed. We have also explained some Distributed Hash Table (DHT) protocols in this chapter. The advantages and challenges in P2P networks have also been discussed. The detail of experimental survey has been presented to identify the problem.In Chapter 2, we explained some basic definitions and a brief introduction of some models presented in past. The other related work has also been summarized in this chapter. In Chapter 3, we present the trust aggregation algorithm called Absolute trust. First we define the local trust and after that, we derived, intuitively, the formula for global trust. We have shown that the proposed global trust exists and have unique value. This can be calculated

by iterative method and thus, can be implemented in a distributed system. The Absolute trust algorithm is evaluated through simulated experiments and compared with the other existing algorithm. Simulation results have been presented in the same chapter. In Chapter 4, we present a generalized analysis of convergence of Absolute trust. We have derived the proof of convergence mathematically and gave some numerical example to justify it. In Chapter 5, we address the problem of unfairness and free-riding in P2P network. We present a mechanism named Biased Contribution Index (BCI). In this mechanism, the contribution of peers are biased in such a way that they are motivated to download from low contributing peers and upload to high contributing peers. As a result, upload and download amount in each peer gets balanced. We have also given the solution of BCI and justification of fairness in this chapter. The BCI can be calculated by iterative method and can also be implemented in a distributed system. Finally the BCI is evaluated through simulation and compared with the other mechanism. In Chapter 6, we present a simplified form of BCI named Simplified Biased Contribution Index (SBCI). We consider some design rules and define the formula for SBCI. In this formula, peers are motivated to choose the transacting partner in same way as in BCI. The iterative calculations are not needed in SBCI unlike in BCI and in the other methods. Thus, it is very simple to implement in the network. We have given the mathematical justification for design rules for fairness. The SBCI is also evaluated through simulation in this chapter. We have given two different methods for peer selection and compared the simulation results with the other mechanisms in the same chapter. In Chapter 7, we conclude the thesis and present some open problems for possible future work.

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Title : NovelVideoDecomposition Techniques and Their Applications
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Supervisor : Gupta Sumana& Venkatesh K S

Abstract

This thesis presents novel algorithms to decompose a video into background and feature videos. Unlike the existing low rank sparse decomposition methods, the proposed decomposition techniques have significantly reduced computational complexity. Moreover, the proposed algorithms are completely parallelizable, which make them better choices for presently available advance multicore processors. The parallelizable property of the proposed decomposition algorithms also ensures that large video shots can be processed, which was not hitherto practically feasible with most of the existing decomposition algorithms. This opens up new possibilities for decomposition based techniques and encourages us to explore the effectiveness of video decomposition in diverse fields of video processing. First, we discuss the novel decomposition schemes and observe the effect of various design parameters on the respective algorithms. This will not only help to understand the proposed decomposition schemes better but also helps to choose necessary parameter values for various applications. The parallelizable nature of the algorithms is discussed, along with necessary timing comparison, with the existing decomposition algorithms. Next, we apply the proposed decomposition algorithm to detect salient regions in a video. At first, we use video decomposition to extract motion salient regions from videos captured with static cameras and show that the extraction of motion saliency using video decomposition is superior to a large class of existing methods. This work is followed by detection of visually salient regions in videos captured with camera motion or dynamic contents. The results demonstrate that the use of video decomposition results in accurate detection of salient objects and the detected regions closely resemble actual human eye tracking data. Finally, we go beyond visual perception and detect motion in scenes where motion is nearly or completely imperceptible due to its low magnitude, low frequency or both. We classify the detected motion to design a simple noninvasive method to monitor physical or biological events. As decomposition algorithms are able to separate spatiotemporal discontinuities in video, we further use video decomposition algorithms to accurately detect several artifacts in archival movies and use the detected mask for localized restoration to ensure maximum quality in the restored videos. We address some common artifacts observed in old movies, like partial color artifacts, blotches, scratches, dust, intensity flicker etc., and also discuss the effectiveness of video decomposition algorithms in various restoration processes. We demonstrate restoration results for some videos naturally degraded by single or multiple artifacts to illustrate the effectiveness of the proposed restoration algorithms in real world applications. Finally, we demonstrate some diverse applications of video decomposition in video processing. We demonstrate how decomposition can be used to summarize a video into an image using motion segmentation, to filter out temporal fluctuation commonly present in cheap depth cameras like Kinect or to generate a video storyboard. We conclude the work by analyzing this diverse set of applications to establish that video decomposition can be an effective tool in many video processing applications and the usage of video decomposition becomes practically feasible in many of these cases because of the parallelizable nature of the proposed algorithms.

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Title : *Leader-Follower-Based Formation Control of Multi-Satellite & Multi-Robot Systems using Sliding Mode Techniques*

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Supervisor : *Behera Laxmidhar*

Abstract

This thesis work is concerned with the development of formation control laws for multi-satellite and multi-robot systems in a leader-follower-based configuration. Control algorithms have been derived using robust sliding mode techniques. Reduced chattering, finite time convergence, requirement of no apriori knowledge of the disturbance bound and guaranteed stability are some of the hall-marks of the proposed control algorithms. Proposed algorithms have been validated through extensive simulations for multi-satellite systems, while experimental validations have been provided for multi-robot systems. The tracking control problem of a group of satellites making a circular formation in a leader-follower framework is solved using Artificial Potential Field (APF) method for path planning and Fuzzy sliding mode control (FSMC) technique for designing a robust controller based on Hamiltonian dynamics. The fuzzy parameters associated with the FSMC are estimated using an adaptive tuning algorithm derived based on Lyapunov stability theory. The value of the disturbance bound is not required for tuning of these parameters. This approach also reduces chattering. To ensure fast and finite time convergence, the fast non-singular terminal sliding mode control (FNTSMC) technique has been used to design a robust tracking controller for a two-spacecraft formation flying (SFF) system. A novel Lyapunov-based adaptive fast reaching law has been proposed to deal with the disturbances and uncertainties in the physical system. As an alternative to mitigate the chattering effect, an adaptive fuzzy based fast reaching law is also proposed. The novel adaptation algorithms are designed in such a way that the finite time convergence property of the FNTSMC has been retained. The nonlinear dynamics defined in leader fixed Euler-Hill's frame has been considered for this work and the reference trajectories are generated using linearized force-free Hill-Clohessy-Wiltshire equations of motion. Considering the relevance of optimal control strategies in space systems, a decentralized optimal control algorithm based on nonlinear model predictive control (NMPC) technique has been designed for the tracking control of SFF system. To estimate the velocity as well as unmeasured disturbances from the noisy position measurements, and hence, to improve the precision of prediction model, an adaptive higher order sliding mode observer has been incorporated in the proposed NMPC scheme. Novel adaptive tuning algorithms are derived based on Lyapunov theory, for updating the observer gains, which gives enough flexibility in the choice of initial estimates. The trajectory tracking problem is formulated as a finite horizon optimal control problem, with control constraints, which is solved online. A novel adaptive update law has been derived for tuning the step size in optimization algorithm, as an alternative to the heuristic choice of it for diverse operating conditions. The implementation issues of the SMC-based formation control scheme has been analysed using a multi-robotic system. To ensure fast and finite time convergence, as well as to improve the fault tolerance capability of the formation, a fast adaptive gain NTSMC has been proposed for the tracking control of non-holonomic robots in leader-follower based formation. A fast adaptive reaching law has been proposed, and the novel adaptive update laws are derived for updating its parameters to ensure the finite time stability of the system. The fault tolerance capability of the formation, i.e. the ability of the formation to retain its stability, even if it gets reconfigured owing to the isolation of one or more critically faulty agents, has been validated using a residual-based synchronous fault detection (FD) scheme. The APF based path planning module has been redefined in terms of FD parameters to facilitate the isolation and formation reconfiguration. Fuzzy based fast adaptive reaching law is also proposed as an alternative to reduce the chattering problem. Rigorous perturbation studies are conducted based on real

time experimentations done using Pioneer P3-DX as well as FireBird VI robotic platforms, to confirm the efficacy of the proposed strategy. For improving the reliability of a formation in complex real time applications, a resource optimal, novel finite time event triggered integral sliding mode control (ISMC) scheme has been designed for the consensus-based tracking control of a multi-robotic system (MRS) with bounded disturbances. The finite time consensus convergence as well as finite time sliding mode stability has been proved through Lyapunov- based analysis. A lower bound for the inter-execution time has been derived to ensure that the zeno behavior does not exist. The proposed control protocol has been developed for a leader-follower formation framework, such that the desired relative state deviation between the agents can be achieved with a directed graph topology. The theoretical results are validated, and compared with that of the recent relevant works through real time experimentations performed using Pioneer P3-DX as well as FireBird VI robots.

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Title : Spectral response analysis of single layer organic semiconductor devices
Author(s) : Kumar Sandeep
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Supervisor : Iyer S Sundar Kumar

Abstract

There has been a significant progress in the field of organic electronics in the last two decades primarily motivated by their potential for low cost, low temperature solution processing, compatibility with flexible substrates and being a greener technology compared to inorganic electronics. However, to achieve their full potential, better performance of organic electronic devices is imperative, which requires improved characterisation and better understanding of these devices. In this thesis, characterisation techniques of single layer organic semiconductor devices have been developed based on spectral response (SR) measurements in the ultra-violet and near infra-red spectral range. In the initial part of the thesis, signals of internal photo emission (IPE) from the electrodes to the organic semiconductor layers are analysed to evaluate the metal-organic semiconductor (MO) barrier for electron and holes – a critical parameter for designing organic semiconductor devices. The IPE signal however is buried in the photoconductive (PC) signals of the photovoltaic active layer in the device. Two methods – (i) comparing SR of devices with different electrodes and (ii) analysis of device SR under different bias conditions have been proposed and their utility demonstrated. In order to more clearly discern the SR signal, taking ratios of the SR signals under different device bias conditions have been proposed. The ratios technique developed allows a more objective discernment of IPE signal from PC component within the total SR signal. The symbatic and antibatic nature of the SR with respect to the absorption spectrum of a single layer device is investigated based on the first principle optoelectronics calculations of physical models. The potential for tune-ability of the SR with device thickness and applied bias has been investigated. This property can find applications in optical demodulation systems. The analysis methods developed in the thesis have been then used to study and extract parameters of single layer test devices fabricated with single walled carbon nanotubes as a transparent electrode.

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Title : Efficient Risk Management Of Power Producers In Short Term Electricity Market Using Probabilistic Techniques

Author(s) : Panda Debasmita
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Supervisor : Singh Sri Niwas

Abstract

Decision making problems in electricity markets involve maximizing profits (i.e., financial profit of a power producer) or minimizing costs (i.e., procurement cost of consumers) in risky environments. Generation companies (GenCos) are major players in an electricity market. Their decision making in risky environments involves multiple challenges such as, portfolio formulation, consideration of risk sources and selection of proper risk handling techniques. The uncertain nature of the market and operational parameters makes the decision making process difficult. In stochastic programming, uncertain data is modeled as a stochastic process. The profit or cost function is random in nature and can be modeled probabilistically. The greatest challenge in risk management is to model these probabilistic uncertain factors. The most common way of optimizing a function characterized by probability distribution of random variable is, by considering its expected profit. However, the main drawback of this approach is that the other probabilistic parameters of the random variable are ignored. Therefore a proper scenario modeling technique is required to address the random nature of uncertain variables. Again, simultaneous movement of multiple energy and reserve markets makes the decision making process more complicated and needs proper modeling approach to get an optimal profit-risk trade-off. The first and foremost task is to develop a conditional value at risk (CVaR) based risk model for both physical and financial risk evaluation considering multiple market involvement. Cross-border markets involve congestion charges. Hedging of such monetary losses to the producer can be made through financial instruments. Many electricity market risk models such as optimal involvement of future market, option hedging, and use of derivatives have been reported in the literature. A majority of these considers medium or long-term markets. For short-term and balancing markets where most of the contracts are based on a day-ahead framework, these long-term hedging models are difficult to fit in. Since maintaining the balance between load generation and profit-risk trade-off is important to a power producer, it is essential to develop a short-term hedging strategy. Availability based tariff (ABT) is a key instrument in balancing the real time market in Indian system. This imbalance price signal, known as unscheduled interchange (UI), is variable in nature and can be taken as an uncertain parameter in risk management study of GenCos. In the absence of an ancillary service market, Indian producers should opt for an efficient trading strategy with robust risk mitigation measures. Numerous works have been published for generator profit maximization. However, none of the available literature has included UI uncertainty for risk management of a GenCo. Hence there is a strong motivation to consider UI uncertainties while deciding the offering strategy of a GenCo. Available literature also shows advantages to financial contracts such as, forward, option, swaps and CfDs to mitigate risk in restructured market. Indian electricity market lacks financial hedging instruments. Therefore, a financial option based market model is helpful in meeting optimal profit-risk trade-off and simultaneously maintaining system balance. Most electricity market uncertainties are modeled probabilistically taking normal distribution of their density functions. Handling uncertainties through scenarios require selection of appropriate joint distribution of uncertainties through rank correlation. Most of the literature includes mean-variance technique to model the correlation between uncertain parameters which follows a Gaussian distribution. This may not always be the case always in an electricity market. Therefore the selection of exact probability distribution through joint correlation is necessary while dealing with risk management models. Consequently, new scenarios can be generated using the estimated multivariate distribution function, thus making the stochastic analysis more accurate. Optimal self-scheduling of power producer is an important decision in a risky environment. It involves maximization of profit while meeting operational constraints. Modeling this is complicated because of the presence of several uncertainties. These Uncertainties need to be modeled properly along with system

on/off status, ramp up/down limits and generation capacity limits. This makes the self-scheduling problem even more complex and needs multi integer non linear (MINLP) programming technique to solve it. Studies performed so far mostly consider price uncertainties in both day-ahead energy market and reserve services. In most literature, uncertainties are handled through scenarios using heuristic techniques or through multistage scenario tree construction. However, with multiple uncertainties, a proper modeling strategy is required considering inter-dependency between the uncertainties, followed by scenario generation. These generated scenarios can be fed to the self-scheduling model to get an accurate profit-risk trade-off strategy for the producer. Therefore, there is a need for stage wise self-scheduling model for producers participating in multi-auction electricity markets. In view described above, the main objectives of the research work carried out in this thesis are as follows, • The first objective is to develop a risk management model for GenCos in multi auction based day ahead market and to show the effect of opportunity cost while dealing with reserve market. It also shows the effect of price uncertainties on GenCos output schedule. • The second objective is to develop a risk management model for the power producers in Indian electricity market, facing penalty side risk due to unscheduled interchange in balancing market. • The third objective is to deal with financial losses that the GenCo may face while participating in inter zonal transaction. An option based hedging strategy is proposed to manage the portfolio risk. A case study based on NordPool market is given. • Finally the last objective is to develop a copula based CVaR model for optimal self scheduling of GenCo. This technique allows incorporation of realistic marginal distribution that captures essential empirical features of risk sources. This thesis has been organized in seven chapters. Chapter 1 briefly introduces the risk management need, risk evaluation techniques, risk management time horizon and its application, and presents relevant literature review on the topic of proposed research work. Finally, it sets the motivation behind the research work carried out in this thesis. Chapter 2 proposes a risk model for a GenCo that provides a proper trade-off between maximum profit and minimum risk in a competitive electricity market. The analysis is restricted to the producer acting as price taker. Probabilistic forecast of market price is taken and the maximization of expected daily profit of the Genco is carried out. The effect of ancillary services on physical and financial risk evaluation of the generator is shown. The conditional value-at-risk (CVaR) technique is employed to measure the associated risk. Chapter 3 presents an attempt to develop a planning model for a generator considering the UI payment structure. An UI based risk assessment model that is peculiar to Indian electricity market is proposed. The proposed approach consists of two stages. The first stage does the diversification through portfolio optimization. UI uncertainties along with spot price uncertainties are taken up in deciding producers offering strategies. The second stage is hedging UI risk with real option instrument. With sudden generation load imbalance, the producer's decision to utilize available options to save itself from paying higher penalty is obtained through this model. In Chapter 4, a mean variance approach is proposed to investigate short term commercial decisions of a GenCo holding contracts with multiple locations subject to congestion effect. A scenario generation model is proposed to govern the stochastic evolution of spot prices. Backward reduction (BR) algorithm is used to reduce the number of scenarios and facilitate the construction of scenario tree. Variance-covariance relation between the expected profit and risk is considered to generate the trade-off curve. A case study based on a realistic market is presented. Chapter 5 proposes a risk-based self-scheduling model considering the marginal distribution of uncorrelated parameters. The uncorrelated parameters are modeled using Copula. A best-fit analysis has been performed in creating data set for the considered variables. Outage scenarios are considered using probabilistic technique through forced outage rate. Further, an individual stochastic self-scheduling problem is formulated for a GenCo considering uncertainty brought by revenue and cost side markets. In Chapter 6, GenCos self-scheduling problem is proposed which considers the UI risk. The risk of generator outage is modeled with a scenario generation technique using Markov's chain. Multiple sources of risk are considered for the GenCos self-scheduling problem with CVaR as a risk measuring technique. The proposed approach is then, demonstrated on a GenCo situated in the Northern region power market of India. Finally, Chapter 7 summarizes the main findings of the work presented in this thesis and suggests possible scope for future research work in this area.

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Title : Perceptual Attributes in Video Summarization
Author(s) : Thomas Sinnu Susan
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Abstract

The enormous growth of video content in recent times has raised the need to abbreviate the content for human consumption. Information about the movement patterns of detected objects would best be concatenated into a single image. It contracts browsing time and reduces spatiotemporal redundancy, while perpetuating the nub of the clip content and the impression of motion. We address fully automated reference frame selection and frame removal for an automated video shot summary. There is a need for video summaries of a quality that meets the requirements of human users. We introduce object based attributes of human visual system (HVS) such as color, contrast, intensity, size, shape, and speed of an object for information prioritizing and filtering of frames in video summarization. We quantify these attributes based on motion contrast, motion energy, and motion chromism. These emphasize perceptually significant events while simultaneously eliminating perceptual redundancy from the summaries. We present an optimization framework for static and dynamic cameras. We present an optimized selection of salient activities in the video. We introduce the saliency cost function using object based attributes of HVS. Content-based video retrieval and video synopsis are generally considered as two different areas. Given a query image/images, we present an efficient approach for video retrieval based on single summarized database of the videos as an index. It reduces retrieval latency and memory requirement of the system. We propose a novel colorfulness feature for similarity measure and we also use visual saliency as the feature to retrieve the candidate video. Road accident detection and vehicle behavior analysis is of great interest to the research community in intelligent transportation systems. We present perceptual video summarization techniques to enrich the speed of visualizing the accident content from a stack of videos. The problem of vehicle analysis is formulated as an optimization problem. The results establish the versatility of the proposed summarization framework.

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Title : ***Studies on Multi-band and Broadband Absorbers based on Passive/Active Frequency Selective Surfaces***

Author(s) : ***Ghosh Saptarshi***

Roll No : ***13104185***

Supervisor : ***Srivastava Kumar Vaibhav***

Abstract

Electromagnetic (EM) wave absorbers have drawn significant research attention due its widespread applications such as radar cross-section reduction, stealth technology, EM interference, EM compatibility, wireless communication, and so forth. Conventional microwave absorbers are usually fragile, bulky, and have large surface mass density, which restrain them from using in many practical applications. With the advent of FSS based approaches, absorber technology has been developed to reduce the bulky size and improve the absorption performance. However, they usually suffer from limited bandwidth as they are designed using resonance phenomenon. Several techniques, such as multi-resonating structures, multi-layer geometries are implemented to increase the absorption bandwidth, but these methods fail to increase the bandwidth beyond a few hundred MHz. Circuit analog (CA) absorber is therefore an effective solution to resolve this narrow-bandwidth problem, where broadband absorption is realized by appropriately depositing resistive and conductive patterns on a dielectric substrate. Although the use of resistive patterns can increase the bandwidth of CA based FSS absorbers, they remain passive structures with fixed reflectivity characteristics. A passive FSS might have limited applications due to inflexibility after fabrication; whereas an active FSS (AFSS) based absorber has reconfigurable properties owing to external stimuli. A switchable absorber can serve the purpose of an absorber as well as a reflector just by changing the bias voltage of the design. On the contrary, a tunable absorber, operating in a wide frequency range, may replace a broadband absorber in few applications. Therefore, a lot of research about these reconfigurable absorbers has been carried out recently. However, most of the earlier reported reconfigurable structures suffer from polarization-sensitive behavior, which is quite undesirable for many practical applications. Besides, no dual-band/multi-band switchable/tunable absorber has been reported till date to the best of our knowledge. Furthermore, the tuning ranges of the existing tunable absorbers are limited and need to be further improved. The motivation behind this thesis is to resolve all the above limitations through presenting different types of passive/active absorber structures. In the initial chapters, various passive FSS designs are presented to realize bandwidth-enhanced/ broadband absorbers using different approaches (multi-resonating structures, multi-layer geometry, and circuit analog concept). In the subsequent chapters, these concepts are utilized to exhibit single-band, multi-band, as well as broadband reconfigurable absorbers. All the proposed designs are four-fold symmetric in nature, thereby exhibiting polarization-insensitive characteristics unlike the earlier reported AFSS based structures. Novel biasing techniques have also been implemented to regulate the active components mounted in the fabricated prototypes, whose measured results are in good agreement with the simulated responses.

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Title : Unconditionally Stable Three-Dimensional LOD-FDTD Methods for Low Numerical Dispersion Error

Author(s) : Saxena Alok Kumar
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Supervisor : Srivastava Kumar Vaibhav

Abstract

The finite-difference time-domain (FDTD) method is one of the important numerical techniques for solving electromagnetic problems. As the name suggests, it is a time-domain technique which uses finite-difference approximation to solve the Ampere's and Faraday's law of the Maxwell's equations. For the FDTD method, material properties can be assigned for every unit cell, therefore; it is very suitable for the problems in which highly inhomogeneous materials are used. Moreover, by using a narrow Gaussian pulse, it can be very efficient for the wideband simulation. In this thesis, unconditionally stable three-dimensional four-; five- and six-step locally one-dimensional FDTD (LOD-FDTD) methods are proposed. The proposed LOD-FDTD methods are derived from the three-step LOD-FDTD (LOD3-FDTD) method, and give low numerical dispersion in the desired direction(s). Unlike the LOD3-FDTD method, which has two numerical dispersion relations, the proposed LOD-FDTD methods have only one numerical dispersion relation. Therefore, for every propagation angle, the numerical dispersion characteristic of the proposed LOD-FDTD methods can be known explicitly. Further, the proposed LOD-FDTD methods are implemented for the medium having current sources and lossy materials. Also, in order to simulate any unbounded structure by the proposed LOD-FDTD methods, the convolutional perfectly matched layer (CPML) boundary conditions are implemented for these methods. With the help of the proposed CPML implementation, a line-fed microstrip antenna and a microstrip low-pass filter are simulated here. Furthermore, in order to improve the accuracy of the proposed LOD-FDTD methods, higher-order; hybrid-higher-order and parameter optimized improved LOD-FDTD methods are proposed in the thesis. Moreover, various higher-step LOD-FDTD methods are also proposed here. In the proposed higher-step LOD-FDTD methods, more than two sub-steps have variation in the desired direction(s). As a result, they give lower numerical dispersion in the desired direction(s).

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Title : Low Complexity Detection in Large MIMO Systems
Author(s) : Sah Abhay Kumar
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Abstract

Neighborhood search algorithms have been proposed in the literature for low complexity detection in large/massive multiple-input multiple-output(MIMO) systems. They initialize with a solution vector, and then iteratively search within a neighborhood defined by a fixed symbol distance to obtain the vector which minimizes the Euclidean cost. This may require a search over several intermediate neighborhoods. Further, the maximum-likelihood (ML) solution may not lie in the neighborhoods searched. Motivated by this, we first propose to cut down the size of the neighborhood so that the complexity of such algorithms can be reduced. Secondly, we improve upon their error reliability by not restricting the search within a neighborhood of fixed symbol distance. In this thesis, we realize both the ideas by deriving a likelihood of a location in the solution vector being in error. Using a function of the likelihoods, we identify a few sets of indices, say K, which are likely candidate locations in error. To update the symbols at the selected set of indices, we derive an expression for the update and use it to generate a small set of neighbors. This helps in reducing the size of the neighborhood significantly. We use this reduced set to lower the complexity of the existing neighborhood search algorithms. Further, this reduced set facilitates the proposal of two new search algorithms, namely sequential likelihood ascent search (SLAS) and global likelihood ascent search (GLAS), which improve the performance by not constraining the search into a fixed neighborhood. We also show that both the two algorithms are amenable to lattice reduction (LR) which helps in obtaining two variants leading to further improvements in performance. Despite the better performance of SLAS and GLAS, they still appear to be far from the ML performance. In the next part of the thesis, we strive for a close to maximum likelihood (quasi-ML) performance and propose an iterative breadth-first tree search algorithm. However, due to redundant iterations the complexity will be high, which can be reduced if we can stop the iterations as soon as a quasi-ML solution is achieved. For this we propose two stopping rules, one relies on a constellation based heuristic and the other one uses the distribution of ML cost. It is found that their complexity curves have a cross-over point. Thus, a combination of the two rules provides a quasi-ML error performance at a low-complexity. After establishing its utility for relatively smaller MIMO systems, we evaluate its performance for large MIMO systems. Compared to existing algorithms it is found to be exceptionally better in terms of both error performance and complexity. Another challenge in realizing large/massive MIMO systems is the need for reducing the large number of radio frequency (RF) chains. However, reducing the number of RF chains may affect the detection performance. In the last part of the thesis, we address this issue by using a hybrid combining approach and formulate a signal to interference plus noise ratio (SINR) maximization problem. We argue that using an orthogonal basis of the channel matrix to maximize the numerator of the SINR is a worthwhile approach to pursue and use it to propose a quasi-orthogonal combining (QOC) scheme. We show that the proposed scheme can provide a detection performance close to that of a system utilizing a dedicated RF chain for each receive antenna with less number of RF chains and without increasing the overall computational complexity.

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Title : ***Linear prediction-based data detection inserially concatenated turbo coded SIMO-OFDM***

Author(s) : ***Veludandi Vineel Kumar***

Roll No : ***13104198***

Supervisor : ***Kasturi Vasudevan***

Abstract

An approach for the linear prediction-based detection of serially concatenated turbo coded single input, multiple output - orthogonal frequency division multi- plexed (SIMO-OFDM) signals is presented. The proposed method exploits the high degree of correlation in the channel frequency response, when the length of the channel impulse response is much smaller than the fast Fourier transform (FFT) length. A prediction filter is used to estimate the channel frequency response at the receiver. The inner decoder operates on a supertrellis with just S_{ST} = S_E × 2^{P−1} states, where the complexity reduction is achieved by using the concept of isometry (here 'S_E' denotes the number of states in the encoder trellis and 'P' denotes the order of the prediction filter). Simulation results show that with a diversity order of two, the proposed receiver achieves a bit error rate (BER) of 10^{−5} for a signal-to-noise ratio (SNR) per bit of 8.2 dB with 32 states in the inner encoder trellis and 4 states in the outer encoder trellis. A reduced complexity version based on per-survivor processing for the proposed receiver is also given, which achieves a BER of 10^{−5} for an SNR per bit of 9 dB with just 16 states in the inner encoder trellis. The simulation results are compared with the FFT-based channel estimation approach using pilots in the frequency domain. Though the FFT-based channel estimation approach achieves a BER of 10^{−5} at an SNR per bit of just 6 dB, its throughput is only 24.7% compared to the proposed method whose throughput is 49.55% for the rate-1/2 serially concatenated turbo code. The throughput is defined as the ratio of the number of data symbols to the total number of symbols in an OFDM frame.

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Title : Modeling and Analysis of Head Related Transfer Functions for Spatial Audio Processing

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Abstract

Development of HRTF based Spatial Audio systems has received lot of attention from researchers in the recent past. This interest can be attributed to the increase in the processing capabilities of hand held devices and advancements in virtual reality which have been successful in creating an immersive audio-visual experience to the end user. However, the complexity of sound interaction with human body before reaching the ear canal poses many challenges in HRTF based rendering of spatial audio. Efficient approaches to capture and reproduce spatialized sound are required in this context. One of the primary challenges in HRTF based spatial audio is the modeling and analysis of the HRTFs. Generally HRTFs are measured using an expensive mannequin that models the human pinna, head and torso (HAT) with a very complex and time consuming measurement process in an anechoic chamber. On the other hand, HRTFs can also be modeled analytically using various methods. In this thesis, two new methods for modeling HRTFs are developed. The first method is based on spherical harmonic modeling of 3D sound fields. The structure of the spherical harmonic matrix (SHM) is very important in the discrete limited order modeling of HRTFs. Discrete limited order representation of HRTFs demands a well conditioned behaviour of the Spherical Harmonic Matrix (SHM) in order to avoid over sensitivity to the perturbation errors. As condition behaviour of SHM depends on the choice of sampling scheme, the configuration chosen for HRTF modeling will have an in uence on the accuracy of the HRTF modeling process. Hence a new sampling configuration called the S-design sampling that results in a well conditioned SHM is developed in this thesis. Applications of the proposed modeling method in HRTF reconstruction and geometrical modeling of loud speaker arrays is also studied. HRTF modeling accuracy is compared with traditional configuration like CIPIC Interaural sampling. Ambisonic encoding error analysis of the proposed S-design sampling scheme for geometrical modeling of loudspeaker arrays is compared to the error obtained using T-designs of platonic solids, Fibonacci sampling, and Gaussian sampling is also discussed. The second HRTF modeling method developed in this thesis is based on the principle of HRTF group delay decomposition. In general, HRTF can be decomposed into its minimum phase and all pass components. Traditional minimum phase pure-delay model approximates the all pass component of HRTF with a constant delay in order to reduce the cost of binaural synthesis. However, direction dependent minimum phase modeling of HRTFs can capture spatial cues contributed by the all pass component in the directions where they are signi cant. In this context, a novel minimum phase HRTF model is developed which is realized as a cascade of the pure minimum phase HRTF model and an all pass lter. The all pass filter is itself designed from the specifications obtained from the all pass component of the HRTF. Experiments on rendering binaural audio are conducted to evaluate the performance of the HRTFs obtained using the proposed method and compared with HRTFs of minimum phase pure-delay model and measured HRTFs. Another important research issue in HRTF based spatial audio is the interpolation of HRTFs. Measurement of HRTFs in anechoic chamber is a tedious task and can only be performed for a finite number of directions. Interpolation of HRTFs is therefore required to obtain HRTFs for all directions over a spherical surface. However interpolation of HRTFs is generally performed by utilizing only the HRTF spectral magnitude. In this thesis, a novel HRTF interpolation method that interpolates HRTFs from adjacent angles by imposing linear phase constraints is developed. The interpolation is formulated as a constrained optimization problem and then solved using some relaxation criteria. The method is thoroughly evaluated by conducting experiments on binaural audio synthesis

and compared with conventional interpolation methods available in literature. Personalization of HRTFs addresses the issue of obtaining HRTFs of a new subject from the HRTFs of existing subjects without actually measuring the HRTF of a new subject. The anthropometric parameters of a human subject can be used for HRTF personalization. In this context, a joint sparsity and linear regression based method is developed for identifying the dominant anthropometric parameters of human subjects first. The personalized HRTFs are subsequently obtained utilizing these dominant anthropometric parameters. Exhaustive evaluation of the personalized HRTFs is carried out and results are illustrated using pinna spectral notch error analysis, and log spectral distortion as compared to the ground truth HRTFs. The closely related topic of binaural source localization is also addressed in this thesis. A new frequency domain based HRTF data model with enhanced frequency diversity is developed for binaural source localization herein. The proposed method enhances directional information in the received binaural signals. This leads to an improvement in localization performance when compared to earlier methods. Subsequently, a subspace based approach is used for localizing sound sources. The evaluation of the proposed method is carried out on a low cost dummy mannequin (MiPS mannequin) with bionic ears designed in our Lab using 3D printing technology. The bionic ears are 3D printed using silicone material which is resilient in nature. A HRTF database is also developed using this mannequin which is available for research purpose on request. The proposed binaural localization method is evaluated using this HRTF database and compared with existing binaural source localization methods.

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Title : Modeling and Analysis of GaN HEMTs for Power-electronics and RF Applications

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Supervisor : Chauhan Yogesh Singh

Abstract

Gallium Nitride (GaN) High Electron Mobility Transistors (HEMTs) and their associated power-electronics and RF applications have been a topic of academic and industrial research over the past couple of decades. This is due to the commendable level of performance promised by the GaN material system and the heterojunction that it forms with AlGaN, leading to features such as high breakdown voltage, high mobility, high saturation velocity, high sheet carrier density, the ability to withstand high operating temperatures etc. In order to take full advantage of these properties and to translate them into viable circuit applications, a robust and accurate GaN HEMT compact model is urgently needed. The existing literature encompasses a huge variety of models that are primarily empirical, table-based, artificial neural-network based or X-parameter based models. Such models obscure the device-circuit interactions as they are not based on the physics governing the various behavioural nuances and device dynamics. High fidelity physics-based compact models for GaN HEMTs, particularly surface-potential-based, are desirable and the industry is looking for them for multiple reasons. First, GaN technology is still not fully matured and a physics-based model would help a great deal in the device design and therefore in the evolution of the GaN technology itself. Second, a physics-based model offers a relatively smaller set of parameters whose flow of extraction is simple and can be related to the intrinsic device physics, leading to a more meaningful model card. Finally, physics-based models are inherently scalable with regard to bias, temperature or geometry, which is of great significance to circuit designers as they can explore a wider design space. GaN HEMTs exhibit certain non-idelities in their behaviour, such as currentcollapse, knee walk-out etc., which are manifestation of trapping effects within the device. A good compact model is supposed to capture this behaviour very well as this non-linearity severely reflects in the large-signal harmonic balance and load pull characteristics. Moreover, state-of-the-art models are also expected to accurately model the device characteristics for multiple bias, temperature and geometry conditions, without compromising on the computational efficiency and robustness at the same time. A desirable feature of the model is simple and well defined parameter extraction flow. Small-signal model parameter extraction for microwave transistors forms a key ingredient of their overall modeling process since it is a prerequisite to the subsequent large-signal and noise modeling. In view of the above, the main objectives behind the research work carried out in this thesis are as follows: a) to develop a physics-based capacitance model for multiple field-plated GaN devices for accurate switching behaviour, to perform numerical and mixed-mode simulation to study the impact of field-plates on circuit switching transients, validation against commercial power GaN device. b) to present an RF compact model for GaN HEMTs for small-signal and large signal RF simulations, develop a comprehensive parameter extraction methodology, validation of the model and extraction procedure against broadband measured S-parameters, harmonic-balance and load-pull data, carry out statistical simulation study using proposed model. c) to study large gate-periphery GaN devices for novel parameter extraction methodologies, to mathematically understand the stability behaviour of GaN devices particularly the impact of via-inductances on Rollett's stability factor. d) to analyze and model kink-effects observed in high frequency characteristics such as h 21 and S 22 of GaN HEMTs

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